FFIBM/Oppdr 311501/138

Approved
Kjeller 31 January 2000

Bjørn Arne Johnsen
Director of Research

PENETRATION ANALYSES OF PROTECTIVE SUITS AND BOOTS AGAINST JET FUEL (JP-8)

PEDERSEN Bjørn

FFI/RAPPORT-2000/00660

FORSVARETS FORSKNINGSINSTITUTT
Norwegian Defence Research Establishment
P O Box 25, N-2007 Kjeller, Norway

FORSVARETS FORSKNINGSINSTITUTT (FFI)
Norwegian Defence Research Establishment

P O BOX 25
2007 KJELLER, NORWAY

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

REPORT DOCUMENTATION PAGE

1) PUBL/REPORT NUMBER	2) SECURITY CLASSIFICATION	3) NUMBER OF PAGES
FFI/RAPPORT-2000/00660	UNCLASSIFIED	16
1a) PROJECT REFERENCE	2a) DECLASSIFICATION/DOWNGRADING SCHEDULE	
FFIBM/Oppdr 311501/138	-	

4) TITLE
PENETRATION ANALYSES OF PROTECTIVE SUITS AND BOOTS AGAINST JET FUEL (JP-8)

5) NAMES OF AUTHOR(S) IN FULL (surname first)
PEDERSEN Bjørn

6) DISTRIBUTION STATEMENT
Approved for public release. Distribution unlimited. (Offentlig tilgjengelig)

7) INDEXING TERMS IN ENGLISH:	IN NORWEGIAN:
a) Penetration	a) Penetrasjon
b) Protective suits	b) Beskyttelsesdrakter
c) Protective boots	c) Beskyttelsesstøvler
d) Jet fuel	d) Flydrivstoff
e) Breakthrough limit	e) Gjennombruddsgrense

THESAURUS REFERENCE:

8) ABSTRACT

Penetration analyses with jet fuel have been carried out on three different protective suits and one pair of protective boots. The analyses were performed with a single cell permeation system developed at Norwegian Defence Research Establishment, Division for Protection and Materiel (FFIBM). A permeation rate of 1 µg/(cm^2 min) was used as breakthrough limit in these analyses.

The analyses showed that the protective suits had limited protection against jet fuel based on our test criteria. The protective boots showed better protection properties.

9) DATE	AUTHORIZED BY This page only	POSITION
31 January 2000	Bjørn Arne Johnsen	Director of Research

ISBN 82-464-0398-2

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE
(when data entered)

CONTENTS

PENETRATION ANALYSES OF PROTECTIVE SUITS AND BOOTS AGAINST JET FUEL (JP-8)

1 INTRODUCTION

Norwegian Defence Research Establishment, Division for Protection and Materiel (FFIBM) was asked by Norwegian Air Material Command (LFK) to undertake testing of three different protective suits and one pair of protective boots with regard to jet fuel (JP-8). The tested suits and boots are being considered for work in fuel tanks. Jet fuel was already obtained from LFK.

2 EXPERIMENTAL

2.1 Analytical apparatus

The analytical apparatus used to test the penetration of jet fuel (JP-8) through the protective suits and boots consist of a permeation cell and a flame ionisation detector (FID). A gas stream of nitrogen transports the penetrated jet fuel from the test cell to the detector. The test cell is shown in Appendix A together with the set-up of the system. The tested suits and boots were permeable and because the system uses positive pressure, a thin polyethylene film was applied under the test pieces. This is proved to have no noticeable effect on the penetration of jet fuel through the tested materials. The nitrogen flow through the test cell was approximately 60 ml/min and the FID was operated at 250°C. In earlier tests, 100 microlitre instead of an excess of the penetration agent and also other carrier gas flows were used. These differences does not influence on the breakthrough limit but gives different accumulated penetrated amounts. The results of these tests should only be used to compare the specific test materials.

2.2 Protective suits and boots

Three different protective suits and one pair of protective boots were tested with regard to penetration of jet fuel (JP-8). The area of the test pieces were 12,5 cm^2.

- Test number 1-00: Nomex® IIIA, water repellent
- Test number 2-00: Nomex® IIIA, flame & acid resistant
- Test number 3-00: Dale antiflame protective fabrics
- Test number 4-00: Whites protective boots

2.3 Penetration agent

Jet fuel (JP-8) was used as the penetration agent in these analyses, and an excess of this agent was applied to each parallel. A filter paper was put on top of the test material to get good contact between the penetration agent and the materials to be tested. The test cell was closed with a screw cap to avoid evaporation of the penetration agent. The density of jet fuel is 0,82 g/ml (1).

2.4 Breakthrough limit

The breakthrough limit used in these penetration analyses is in accordance with the breakthrough limit in the Norwegian Standard for testing of protective clothing against liquid chemicals (2). This breakthrough limit, where the analytical apparatus detect a permeation rate of 1 $\mu g/(cm^2\ min)$, were chosen because there are no other available breakthrough limits in relevance to jet fuel. It ought to be mentioned that this limit is not based on any toxicity data for jet fuel and that the test results should only be used for comparing these different test materials. It must also be mentioned that the flow rate of carrier gas through the test cell used in these tests was 60 ml/min compared to the Norwegian Standard which uses 520±52 ml/min. This gives a lower penetration rate through the test materials since the concentration gradient across the material decreases with decreasing carrier gas flow.

3 RESULTS

3.1 Penetration

The results from the penetration analyses for the protective suits and the pair of protective boots with regard to the penetration of jet fuel (JP-8) are given in the tables shown below.

The first table shows the breakthrough time for one parallel of each of the three different suits in accordance with the breakthrough limit in Chapter 2.4. The symbol 0 means that the limit has been exceeded at once. The second table shows the accumulated penetrated amount of the penetration agent for one parallel of each of the three different suits at certain times in the analyses. The following tables show the breakthrough times and the accumulated penetrated amount of jet fuel at certain times in the analyses for three parallels of the protective boots. The curves for penetration rate and accumulated penetrated amount for the protective suits and boots are given in Appendix B.

3.1.1 Protective suits

	Test number 1-00	Test number 2-00	Test number 3-00
Breakthrough (1 µg/(cm^2 min))	0	0	0

Table 3.1 *Breakthrough times for the three different protective suits with regard to JP-8*
0: Breakthrough at once

Accumulated penetrated amount JP-8 (mg/cm^2)	10 min	30 min	60 min	120 min	180 min	240 min	480 min
Test number 1-00	0,11	0,45	0,98	2,00	3,10	4,10	8,00
Test number 2-00	0,09	0,39	0,84	1,80	2,70	3,60	7,20
Test number 3-00	0,08	0,37	0,80	1,70	2,57	3,40	6,80

Table 3.2 *Accumulated penetrated amounts of JP-8 for the three different protective suits*

3.1.2 Protective boots

	First parallel	Second parallel	Third parallel
Breakthrough (1 µg/(cm^2 min))	2 h 36 min	2 h 55 min	2 h 50 min

Table 3.3 *Breakthrough times for the protective boots with regard to JP-8*

Accumulated penetrated amount JP-8 (mg/cm^2)	10 min	30 min	60 min	120 min	180 min	240 min	480 min
First parallel	$2,80\ 10^{-6}$	$3,50\ 10^{-6}$	$2,00\ 10^{-4}$	0,0117	0,0663	0,19	1,30
Second parallel	$1,90\ 10^{-6}$	$8,73\ 10^{-6}$	$9,27\ 10^{-5}$	0,0067	0,0453	0,14	1,20
Third parallel	$4,25\ 10^{-6}$	$1,70\ 10^{-5}$	$1,93\ 10^{-4}$	0,0093	0,0530	0,15	1,10

Table 3.4 Accumulated penetrated amounts of JP-8 for the protective boots

4 DISCUSSION

As expected, the results show that there are large differences in protection properties between the tested protective suits and the protective boots with regard to penetration of jet fuel (JP-8). As for the protective suits, the differences in properties are not so pronounced. The suits are all permeable and they differ only in material thickness and special protective treatments (water repellent, flame & acid resistant, antiflame).

A breakthrough limit based on a permeation rate of 1 $\mu g/(cm^2\ min)$ was used in this study. This limit is not evaluated against any toxicity data for jet fuel and the breakthrough times from this study should only be used for comparing the tested suits and boots. The accumulated penetrated amounts of jet fuel were reported for one parallel of each suit and for three parallels of the protective boot at certain times in the analyses. The results show how fast jet fuel is penetrating the materials when exposed to an excess of this liquid. This gives the Air Force the possibility to evaluate the protective suits and boots tested at FFIBM in accordance with their own requirements.

Test number 1-00, 2-00 and 3-00 are all protective suits of different material thickness and special protective treatments. According to our test criteria, the jet fuel breaks through these suits at once. This is not unexpected since the materials consist of open fabric without an impermeable membrane.

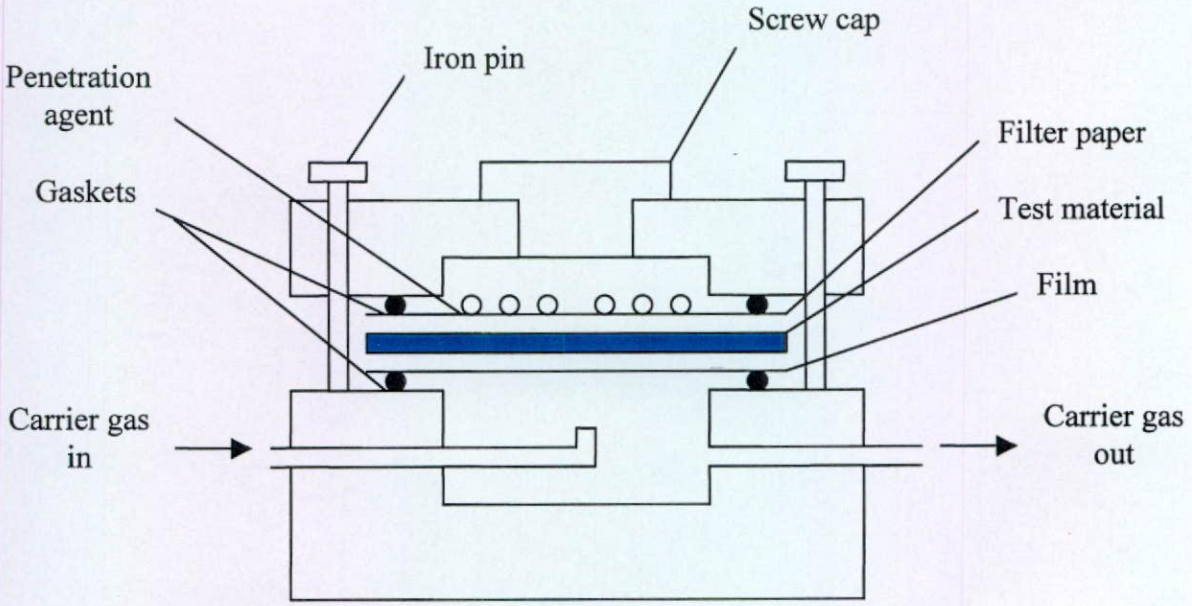
Test number 4-00 is a pair of Whites protective boots. These boots have an average breakthrough time of 2 hours and 47 minutes, according to our test criteria.

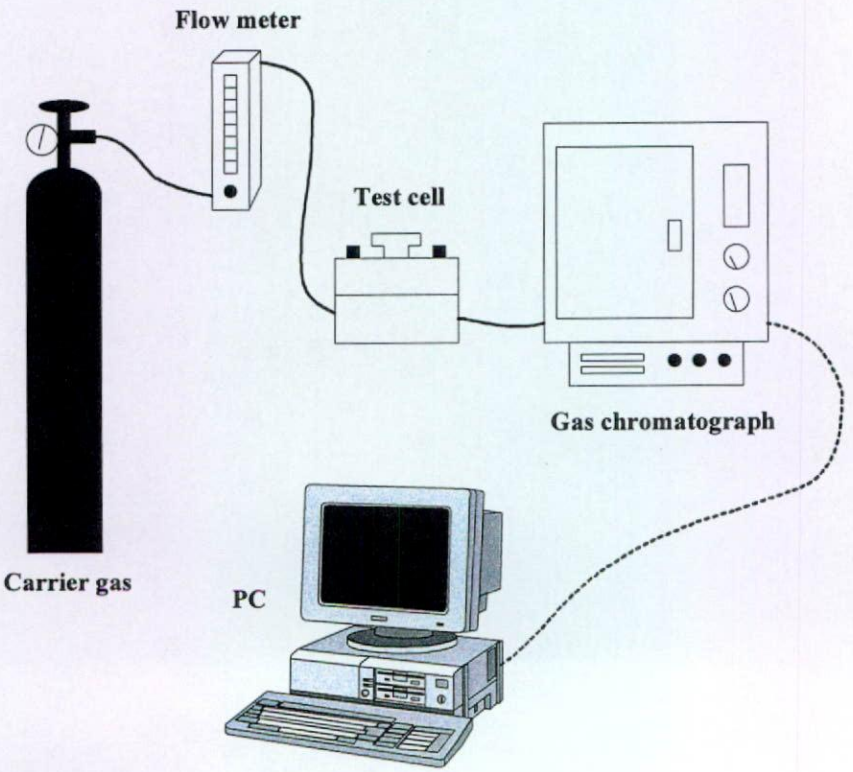
5 CONCLUSION

The results show that the protective suits have limited protection against jet fuel based on our test criteria. The protective boots show better protection properties, but when choosing protective clothing it is important to be aware of the clothes limitations and use them accordingly.

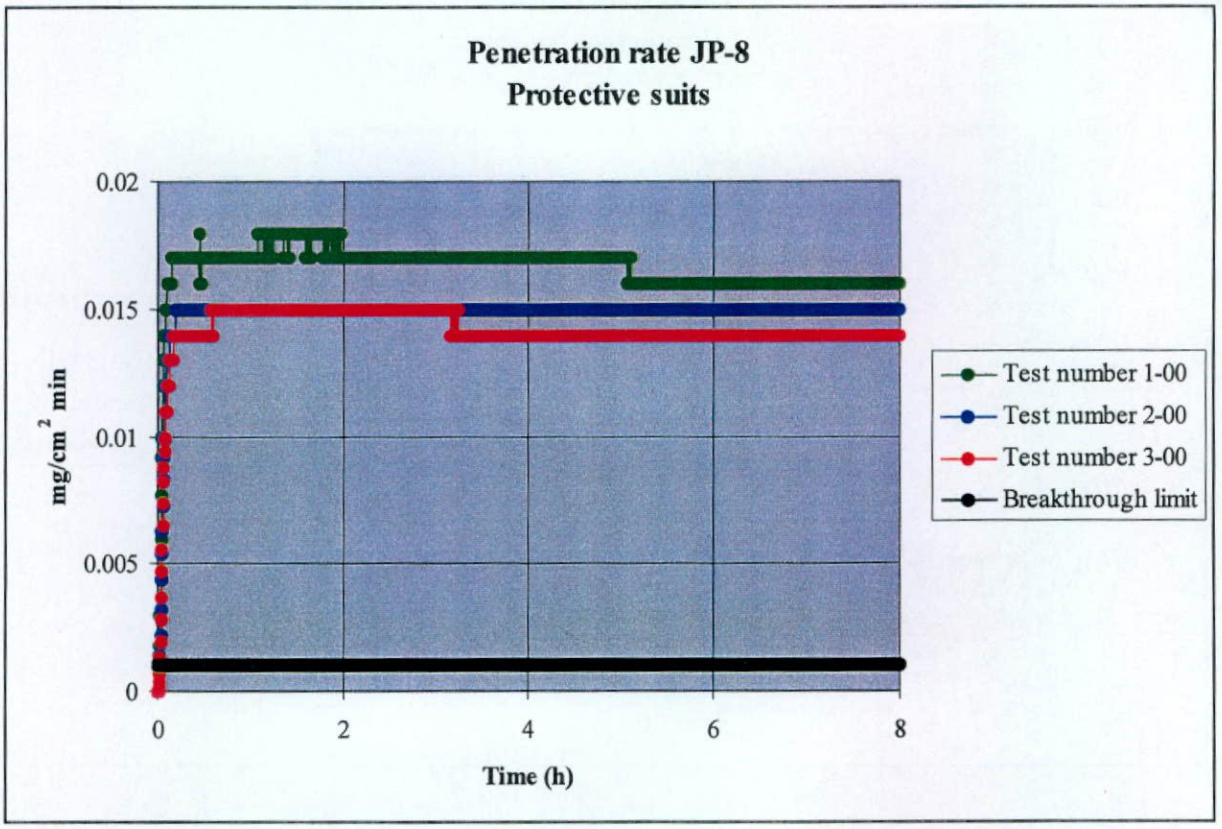
APPENDIX

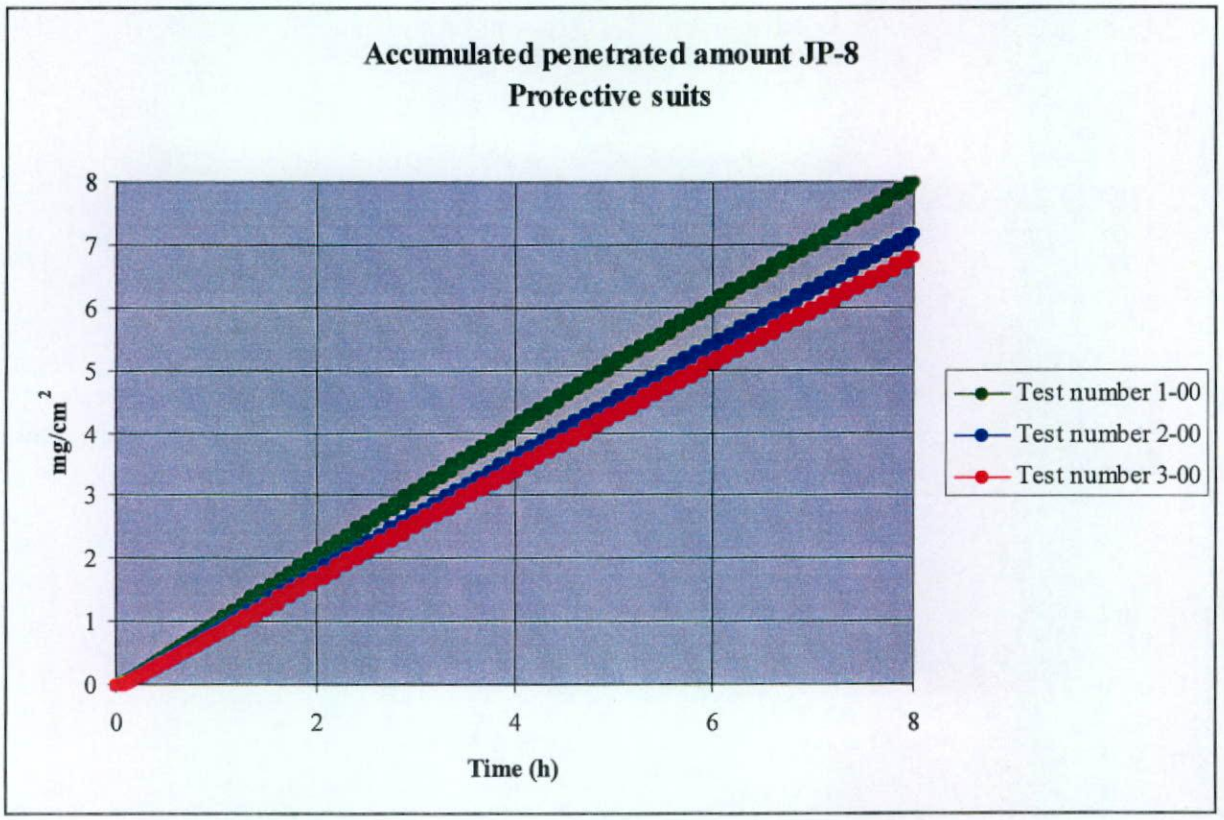
A TEST CELL AND SET-UP OF THE SYSTEM

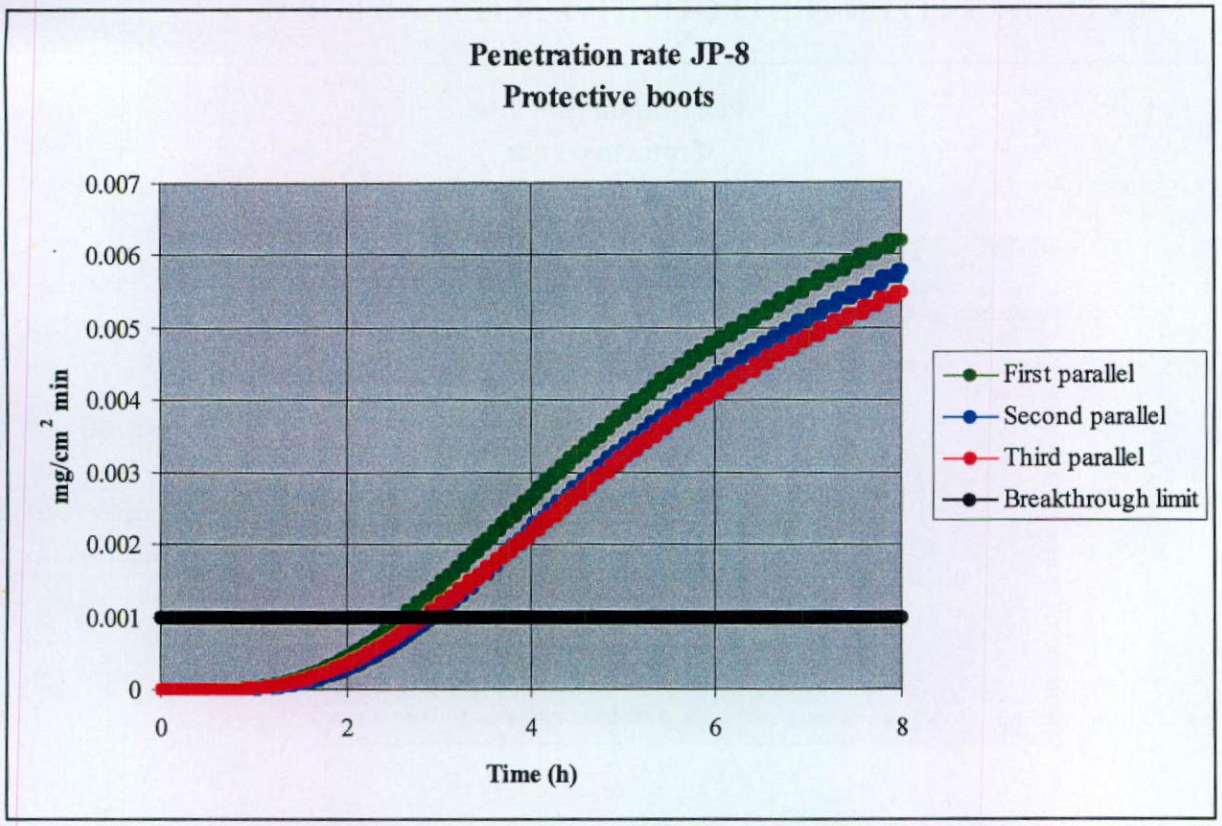


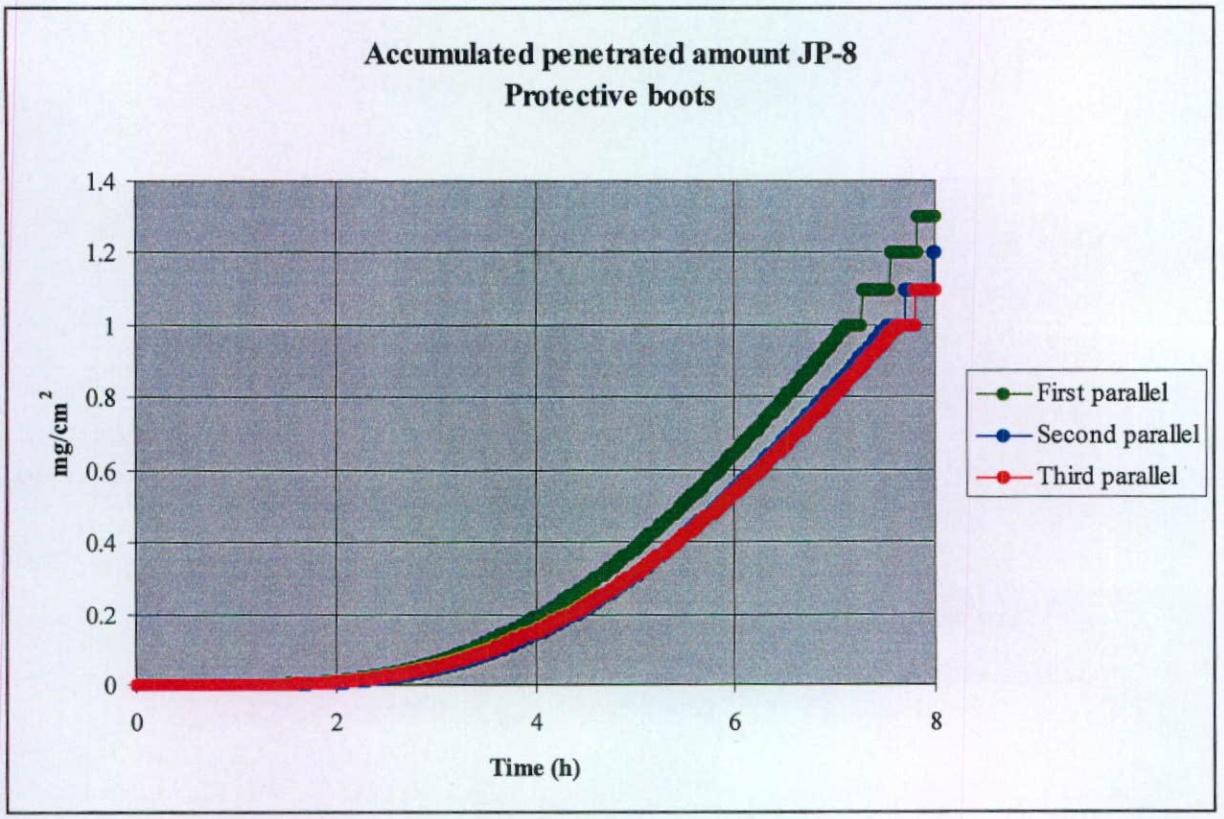


B PENETRATION RATE AND ACCUMULATED PENETRATED AMOUNT OF JET FUEL (JP-8) FOR THE PROTECTIVE SUITS AND BOOTS






Penetration rate JP-8
Protective boots
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
mg/cm 2 min
0
2
4
6
8
Time (h)
First parallel
Second parallel
Third parallel
Breakthrough limit


Accumulated penetrated amount JP-8
Protective boots
1.4
1.2
1
0.8
0.6
0.4
0.2
0
mg/cm 2
0
2
4
6
8
Time (h)
First parallel
Second parallel
Third parallel

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(1) Pedersen B, Johnsen B A (1997): Permeasjonsanalyse av engangshansker (Permeation analysis of protective gloves), FFI/RAPPORT-97/02750, Forsvarets forskningsinstitutt (Offentlig tilgjengelig).

(2) Norges Standardiseringsforbund, Norsk Standard NS-EN 369 (1993): Vernetøy Beskyttelse mot flytende kjemikalier Prøvingsmetode: Materialers motstand mot gjennomtrengning av væsker (Protective clothing Protection against liquid chemicals Test method: Resistance of materials to permeation by liquids).